# STAKEHOLDER MEETING

## ETV DRINKING WATER SYSTEMS CENTER

**Ann Arbor, Michigan**
**November 19, 2002**

**Under a Cooperative Agreement with:**

**U.S. Environmental Protection Agency**
**and**
**NSF International**



**EPA/NSF ETV Drinking Water Systems Center**
**Annual Stakeholder Meeting**
**November 19th, 2002**

## Agenda

## 1. Introductions

### 1.1 Antitrust Statement and Housekeeping Items

NSF directs all attendees to read and agree to the following anti-trust statement.

*"Because this meeting involves representatives of competing businesses, it is important that NSF has everyone's agreement before we begin that the meeting will be conducted in full compliance with the antitrust laws. We must avoid any comment or action that encourages joint action by participating firms to restrict their competition. If any of you have any questions, I refer you to the NSF Antitrust Guide for the conduct of meetings."*

Housekeeping items will be mentioned including schedule of meeting breaks, locations of restrooms, etc.

### 1.2 Welcome & Introductions

The DWS Center would like to welcome you all to the NSF International Offices in Ann Arbor, Michigan.

A special welcome for a new Steering Committee member:
Mr. E. Buck Henderson, Manager in the Public Drinking Water Section of the Texas Commission on Environmental Quality

A special welcome to new NSF DWS Center staff: Mr. Mike Blumenstein, Project Coordinator.

The DWS Center would like to welcome Ms. Teresa Harten, the ETV Program Director, to her first DWS Center stakeholder meeting.

### 1.3 Farewell to Those Departing

The ETV Drinking Water Systems (DWS) Center would like to thank the following Steering Committee member who has departed the Steering Committee since the last meeting:

- Mr. Ed Urheim, Georgia Department of Natural Resources

## 2. ETV Program Update by ETV Program Director Ms. Teresa Harten

Information/overheads to be provided at the meeting.

## 3. ETV Drinking Water Systems Center Overview

### 3.1 Scope, Mission, and Purpose

NSF International entered into an agreement on October 1, 2000 with the Environmental Protection Agency (EPA) to form a Drinking Water Systems (DWS) Center dedicated to technology verifications. NSF cooperatively manages the DWS Center with the EPA. The DWS Center provides independent performance evaluations of drinking water technologies. Special emphasis is placed on systems for small communities. The treatment technologies must address contaminants with potential public health impact. Examples of treatment technology categories are: arsenic reduction, disinfection by-product precursor removal, inorganic contaminant reduction, microbiological contaminant reduction, microbiological contaminant inactivation, nitrate reduction, radioactive contaminant reduction, synthetic organic compound reduction, and volatile organic compound reduction.

The DWS Center performs treatment system evaluations using protocols developed with stakeholder involvement. Unlike many of NSF's traditional programs that certify that a product conforms to the minimum requirements of a standard, the ETV Program is designed to characterize the performance of a technology through the collection and reporting of performance data. There are no pass/fail criteria associated with the ETV process and testing results become public information. Technologies involved in the verification process are issued a Verification Report that fully describes the product and its performance under a predetermined set of test conditions. The Verification Report can be a valuable tool for manufacturers in support of their performance claims, and in achieving regulatory and marketplace acceptance for their product. Participation on the part of the vendors is strictly voluntary.

The ETV DWS Center also develops new protocols for other drinking water treatment system technologies; however, a review of the technology is performed by the Center and the Center's Steering Committee prior to protocol development. Additionally, the DWS Center may conduct some tests under controlled laboratory conditions, to supplement the Center's field testing.

## 4. ETV Drinking Water Systems Center Update

### 4.1 Verification Testing Status

Total Completed Verification Tests (final reports have been issued) = 27
Tests in progress = 7

ETV Reports Issued Since October 2001:

Atlantic Ultraviolet Corporation, Megatron Unit, Model M250 (June 2002)
Osmonics Inc., Model PS 150 Ozone Disinfection System (December 2001)
Pall Corporation Microza™ Microfiltration 3-inch Unit, Model 4UFD40004-45 (March 2002)
Trojan Technologies Inc., UVSwift Ultraviolet System, Model 4L12 (May 2002)

See the testing status sheet on the following page for a full list of the products that have or are participating in verification testing through the DWS Center.

### 4.2 Protocol and Test Plan Status

Total updates and revisions = 29 (8 protocols & 21 Test Plans).
Revisions in progress = 4

Recently updated ETV Protocols Since October 2001:

Arsenic Reduction
Microbiological and Particulate Reduction
Nitrate Reduction
Inorganics Reduction
Synthetic Organic Contaminant Reduction
Volatile Organic Contaminant Reduction
Reduction of Precursors to Disinfection By-Products
Radionuclides Reduction

(see web site for full list of test plans associated with each protocol: www.nsf.org/etv/dws.)

# EPA/NSF ETV Drinking Water Systems Center
# Verification Testing Status Update

| Vendor | Product | Technology | Mechanism and Contaminant of Concern | Status | Field Testing Organization/ Test Site |
|---|---|---|---|---|---|
| Aquasource N.A. - Richmond, VA | Model A 35 Ultrafiltration System | Ultrafiltration | Reduction of *Giardia* and *Cryptosporidium* | Testing and Reporting Completed May 2000 | Gannett Fleming/ Pittsburgh, PA |
| Aquasource N.A. - Richmond, VA | Model A 35 Ultrafiltration System | Ultrafiltration | Reduction of *Giardia*- and *Cryptosporidium*-sized particles | Testing and Reporting Completed September 2000 | Montgomery Watson Harza/ San Diego, CA |
| Atlantic UV Corporation – Hauppauge, NY | Megatron M250 UV Radiation System | Ultraviolet Radiation | Inactivation of MS2 bacteriophage | Testing and Reporting Completed June 2002 | Montgomery Watson Harza/ San Diego, CA |
| Calgon Carbon Corporation - Pittsburgh, PA | Sentinel™ Ultraviolet Reactor | Ultraviolet Radiation | Inactivation of *Cryptosporidium parvum* | Testing and Reporting Completed May 1999 | Cartwright, Olsen and Assoc. (COA)/ Kitchener, Ontario, Canada |
| ClorTec, a Division of Capital Controls, Inc. - Campbell, CA | ClorTec On-Site Hypochlorite Generating System Model MC 100 | Hypochlorite Generation | Production of Sodium Hypochlorite from Sodium Chloride brine solution | Testing and Reporting Completed September 2000 | Gannett Fleming/ Hummelstown, PA |
| Exceltec International Corp., a Subsidiary of Severn Trent Services, Inc. - Sugar Land, TX | ClorTec On-Site Hypochlorite Generating System Model T-12 | Hypochlorite Generation | Production of Sodium Hypochlorite solution and inactivation of *Pseudomonas aeruginosa* | Testing and Reporting Completed January 2001 | ARCADIS Geraghty & Miller/ Lyman, SC |
| Hydranautics - Oceanside, CA | Hydracap™ Ultrafiltration Membrane System | Ultrafiltration | Reduction of MS2 Virus | Testing and Reporting Completed September 2000 | Montgomery Watson Harza/ San Diego, CA |
| Hydranautics - Oceanside, CA | ESPA2-4040 Reverse Osmosis Membrane Element Module | Reverse Osmosis | Reduction of Arsenic | Testing and Reporting Completed March 2001 | COA/ Park City, UT |
| Ionics - Watertown, MA | UF-1-7T Ultrafiltration Membrane System | Ultrafiltration | Reduction of *Giardia*- and *Cryptosporidium*-sized particles and MS2 Virus | Testing and Reporting Completed September 2000 | Montgomery Watson Harza/ San Diego, CA |
| Kinetico, Inc. - Newbury, OH | SW224 Backwashable Macrolite® Pressure Filtration System | Backwashable Depth Filtration | Reduction of *Giardia* and *Cryptosporidium* | Testing and Reporting Completed June 2001 | COA/ Minneapolis, MN |
| Kinetico, Inc. - Newbury, OH | CPS100CPT Coagulation and Filtration System | Coagulation/ Filtration | Reduction of *Giardia* and *Cryptosporidium* | Testing and Reporting Completed August 2001 | COA/ Minneapolis, MN |
| Kinetico, Inc. - Newbury, OH | Macrolite® Coagulation and Filtration System Model CPS100CPT | Coagulation/ Filtration | Reduction of Arsenic | Testing and Reporting Completed September 2001 | COA/ Park City, UT |

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# Verification Testing Status Update

| Vendor | Product | Technology | Mechanism and Contaminant of Concern | Status | Field Testing Organization/ Test Site |
|---|---|---|---|---|---|
| KOCH Membrane Systems - Wilmington, MA | TFC-ULP4 Reverse Osmosis Membrane Module | Reverse Osmosis | Reduction of Arsenic | Testing and Reporting Completed August 2001 | COA/ Park City, UT |
| Lapoint Industries (formerly U.F. Strainrite, Inc.) - Lewiston, ME | Aqua-Rite Potable Water Filtration System | Bag Filter | Reduction of turbidity and *Giardia*- and *Cryptosporidium*-sized particles | Testing and Reporting Completed September 2001 | Gannett Fleming/ Burnside, PA |
| Leopold Membrane Systems - Zelienople, PA | Ultrabar Ultrafiltration System with 60 inch Mark III Membrane Element | Ultrafiltration | Reduction of *Giardia* and *Cryptosporidium* | Testing and Reporting Completed July 2000 | Gannett Fleming/ Pittsburgh, PA |
| Osmonics, Inc. - Minnetonka, MN | Model PS 150 Ozone Disinfection System | Ozone | Inactivation of *Cryptosporidium* oocysts and Calculation of Ct | Testing and Reporting Completed December 2001 | COA/ Minneapolis, MN |
| OXI Company , Inc. - Virginia Beach, VA | OXI-2B Onsite Mixed Oxidant Generator | On-Site Halogen Generation | Production of chlorine and Inactivation of *Pseudomonas aeruginosa* | Testing and Reporting Completed June 2001 | ARCADIS Geraghty & Miller/ Lyman, SC |
| Pall Corporation - East Hills, NY | WPM-1 Microfiltration Pilot System | Microfiltration | Reduction of *Giardia* and *Cryptosporidium* | Testing and Reporting Completed February 2000 | Gannett Fleming/ Pittsburgh, PA |
| Pall Corporation - East Hills, NY | Microza™ WPM-1 Microfiltration System | Microfiltration | Reduction of turbidity; iron and manganese precipitants; and *Cryptosporidium*, *E. coli*, and *bacillus* spores | Testing and Reporting Completed March 2002 | Univ. of New Hampshire (UNH)/ Manchester, NH |
| PCI Membrane Systems - Milford, OH | Fyne Process Model ROP 1434 with AFC-30 Nanofiltration Membranes | Nanofiltration | Reduction of total trihalomethanes and haloacetic acid | Testing and Reporting Completed September 2000 | UNH and Univ. of Alaska (Anchorage)/ Barrow, AK |
| PentaPure, Inc. - West Saint Paul, MN | PentaPure® H-3000-I Mobile Water Purification Station | Modular treatment train with pentaiodide resin | Inactivation of *E. coli* and MS2 virus | Testing and Reporting Completed August 2001 | ARCADIS Geraghty & Miller/ Lyman, SC |
| Polymem - Fourquvaux, France | Polymem UF 120 S2 Ultrafiltration Membrane | Ultrafiltration | Reduction of turbidity, HPC, and coliform bacteria | *Testing Completed – In Reporting Phase* | Carollo Engineers, P.C./Green Bay, WI |
| Rosedale Products Inc. - Ann Arbor, MI | Bag and Rigid Cartridge Filter System Model GFS-302P2-150S-ESBB | Bag and Cartridge Filter | Reduction of *Giardia*- and *Cryptosporidium*-sized particles | Testing and Reporting Completed September 2001 | COA/ Minneapolis, MN |
| Separmatic Filter Company - Milwaukee, WI | Pressure DE Filter (Model 12P-2) | Diatomaceous Earth Filter | Reduction of turbidity, *Giardia*, *Cryptosporidium*, and MS2 virus | *Testing In Progress* | UNH/ Manchester, NH |

# EPA/NSF ETV Drinking Water Systems Center
# Verification Testing Status Update

| Vendor | Product | Technology | Mechanism and Contaminant of Concern | Status | Field Testing Organization/ Test Site |
|---|---|---|---|---|---|
| Separmatic Filter Company<br>- Milwaukee, WI | Vacuum DE Filter (Model VL-16) | Diatomaceous Earth Filter | Reduction of turbidity, *Giardia*, *Cryptosporidium*, and MS2 virus | *Testing In Progress* | UNH/ Manchester, NH |
| Trojan Technologies Inc.<br>- London, Ontario | UVSwift Unit (Model 4L12) | Ultraviolet Radiation | Inactivation of MS2 bacteriophage | Testing and Reporting Completed May 2002 | Montgomery Watson Harza/ San Diego, CA |
| US Filter<br>- Ames, Iowa | US Filter 3M10C Microfiltration Membrane | Microfiltration | Reduction of turbidity and *Giardia*- and *Cryptosporidium*-sized particles | *Testing Completed – In Reporting Phase* | Montgomery Watson Harza/ San Diego, CA |
| Watermark Technologies, LLC<br>- Draper, UT | eVOX® Model 5 Coagulation and Filtration System | Coagulation/ Filtration | Reduction of Arsenic | Testing and Reporting Completed March 2001 | COA/ Park City, UT |
| Zenon<br>- Burlington, Ontario | ZeeWeed® ZW-500 Ultrafiltration Membrane System | Ultrafiltration | Reduction of *Giardia* and *Cryptosporidium* | Testing and Reporting Completed August 2000 | Gannett Fleming/ Pittsburgh, PA |
| Zenon<br>- Burlington, Ontario | ZeeWeed® ZW-500 Enhanced Coagulation Ultrafiltration Membrane System | Enhanced Coagulation and Ultrafiltration | Reduction of turbidity; *Giardia*- and *Cryptosporidium*-sized particles; and MS2 virus | Testing and Reporting Completed August 2000 | Montgomery Watson Harza/ San Diego, CA |
| Zenon<br>- Burlington, Ontario | ZeeWeed® ZW-500 Ultrafiltration Membrane System | Ultrafiltration | Reduction of *Giardia*, *Cryptosporidium*, and MS2 virus | Testing and Reporting Completed June 2001 | CH2M Hill/ Portland, OR |

## 5. Arsenic Technology Testing

### 5.1 Update on Arsenic Removal Testing in Pennsylvania and Alaska

The DWS Center is currently in the process of coordinating three verification tests in the state of Pennsylvania (PA) in cooperation with the PA Department of Environmental Protection (PA DEP). All three technologies involve adsorptive media for the removal of arsenic. The four vendors participating in the project are ADI International, Kinetico/Alcan (jointly), and Water Remediation Technology (WRT). The Field Testing Organization (FTO), Gannett Fleming, is currently writing the Product Specific Test Plans (PSTPs) for these technologies. A status update of the project will be provided at the meeting.

The DWS Center is also currently in the process of coordinating two verification tests in the state of Alaska with the University of Alaska – Anchorage (UAA). One technology involves removal of arsenic by coagulation and filtration. The other technology involves the removal of arsenic with an ozone system.

### 5.2 Should the Center develop a TSTP for oxidation systems that oxidize iron and remove arsenic though co-precipitation?

The Center has been asked to create a TSTP for rapid oxidation systems for arsenic removal. Should a TSTP be developed for rapid oxidation systems that oxidize iron and remove arsenic though co-precipitation? The Center requests annually from the Steering Committee the priorities for developing protocols and Technology Specific Test Plans. In previous meetings, this technology type, in which a process is used such as ozone to enhance oxidation of iron from Fe (II) to Fe (III), which consequently forms a ferric hydroxide floc that co-precipitates with arsenic, was never addressed. Some experts have indicated that any verification of such a technology would be limited to the iron concentrations at a site and hence the transferability of useful information would be limited. Others have said that these types of technologies are very simple and thus ideal for small systems and thus should be covered in the ETV protocol. The question before the stakeholders and the SC is whether technologies that facilitate only the oxidation of iron for purposes of arsenic removal should have a TSTP developed using funds if available from the ETV DWS Center budget? If the answer is affirmative, then NSF would propose this to the EPA for consideration of future funds.

### 5.3 What analyses should be required for arsenic media disposal: Total Arsenic by ICP-MS analyses, TCLP and/or California WET? Arsenic residuals disposal issues.

Stakeholders including states and vendors have indicated to the Center that whenever a waste solid is produced by an arsenic treatment technology, the solid waste should be tested to determine if it is hazardous or not. The Center proposes that for solids produced by adsorptive media and through coagulation and flocculation processes, the solids be tested for the EPA's Toxicity Characteristics Leachate Procedure (TCLP) and the California Waste Extraction Test (WET). The California WET test uses citric acid and deionized water as the extractable solution and a ratio of 10 to 1 (as compared to a 20 to 1 ratio required by the TCLP analyses). If a waste

fails the TCLP analyses it is characterized as hazardous. If it passes TCLP, then it is not. In California, if a waste passes the TCLP then they also perform the California WET test to see if it passes that test. If it fails, then the waste is characterized as hazardous.

## 6. Protocol Developments and Modifications

### 6.1 Change in the "ballot" system for Steering Committee Voting.

During the past two years the Center has seen a reduction in the number of Steering Committee (SC) members responding to issues that the Center solicits their opinion on. Presently the Center operates with a recommendation from the SC when two-thirds or more of its members recommend a protocol or policy to the Center and EPA. Even though we may have 90% or more of those responding to an issue in the affirmative, we became constrained when we did not reach the needed number of recommendations because of non-responsive SC members. Possible solutions:

- Computation of % recommendation based on total responses (exclude all non-responding SC members from the calculation after 3 attempts by mail, telephone and either facsimile or Email).
- Go with consensus of a "meeting" and no ballot as other Centers do it this way
- Use a proxy system.
- Other ideas to prevent log jams from tardy ballot returns?

### 6.2 Harmonization of ETV Protocols with the Enhanced Surface Water Treatment Rule – Long Term 2 (LT2).

The Office of Ground Water and Drinking Water is developing a draft of the LT2 and draft Guidance for LT2 for the states. The ETV DWS Center has been working on harmonizing its protocols with the LT2 guidance (see discussions in stakeholder meetings and conference calls: http://www.nsf.org/etv/dws/dws_meetings.html ).

#### 6.2.1 Modification of the *ETV Test Plan for Membrane Filtration for Particulate and Microbial Reduction* to include laboratory bench scale testing for microbial removal.

The following pages contain the center's proposed modifications to the *ETV Test Plan for Membrane Filtration for Particulate and Microbial Reduction* and the comments received to date from Stakeholders. The proposed modifications involve the addition of a bench-scale laboratory approach for characterizing the microbial removal capability of microfiltration (MF) and ultrafiltration (UF) membranes. This bench-scale laboratory approach is a proposed addition because it is a controlled, safer, and less expensive test alternative than field microbial challenge tests. Please note that the bench-scale laboratory approach would be added to the test plan as an option for microbial challenge testing and that the 30-day field test would still be required.

Other proposed modifications to the protocol as a result of the proposed addition of the bench-scale laboratory approach include mandatory microbial challenges for ETV testing (either bench-scale or field) and a change to suggest the submission of membrane pore size information instead of requiring it as an ETV task (currently Task 4 of the ETV Protocol). All other testing tasks (such as membrane flux and operation, cleaning efficiency, finished water quality sampling, membrane integrity testing, data handling, and QA/QC) will remain as field-testing procedures in the ETV membrane test plan.

These proposed modifications also reflect the Center's effort to harmonize the ETV test procedures with the proposed Enhanced Surface Water Treatment Rule – Long Term 2 (LT2) USEPA guidance language. The proposed section on selection of membranes to test under the ETV Protocol is one example of a modification for the purpose of harmonization with the proposed LT2 guidance.

# PROPOSED PROTOCOL FOR BENCH-SCALE CHARACTERIZATION OF MEMBRANES USING MICROBIAL PROFILING

## INTRODUCTION

One of the primary drivers for the use of low pressure-driven membranes for treatment of drinking water supplies has been the increased emphasis on the removal of microorganisms. Low-pressure membrane processes have been classified traditionally as microfiltration (MF) or ultrafiltration (UF). There is currently no agreement on specifications that distinguish MF from UF. The traditional method for distinguishing UF from MF is pore size distribution or molecular weight cutoff. MF membranes are often considered to have pore sizes ranging from 0.05 μm to 5 μm and UF membranes from 0.005 μm to 0.05 μm. There is considerable overlap between where one may consider MF to begin and UF to end. Moreover, pore size distribution does not provide an accurate or empirically based method to predict microbial removal. The actual classification of these membranes for product marketing relies primarily upon the manufacturer. Of particular note, microbial removal does not currently play a role in determining whether a membrane is classified as MF or UF. This point leads to confusion in the water community as to the classification of low-pressure membranes. If membranes are to be employed on a more widespread basis for microbial removal, then their classification should be based on their capability to remove microorganisms, not on their pore size distribution.

Microbial removal is usually evaluated through pilot testing. However, rigorous microbial challenge studies at pilot scale are often prohibitively costly. Since pilot studies are typically conducted at water facilities, opportunities for microbial challenge studies may be limited because of the potential hazard of working with microorganisms in proximity to drinking water supplies. Further, membranes are most vulnerable to microbial passage when they are first put online. The complexities of sampling for microbial agents immediately after pilot plant startup may provide inconsistent results due to cake layer accumulation or pore constriction from adsorption of natural organic matter onto the membrane.

This document provides a protocol to evaluate microbial removal by membranes at bench scale. Materials for most low-pressure membrane filtration modules used in drinking water treatment have a hollow fiber geometry. Nonetheless, this protocol can be employed for other geometries (i.e., tubular) with little modification. Its intent is to provide a widely accepted, standardized methodology with which to characterize membranes from a microbial perspective. The absence of natural water constituents in the feed will allow accurate assessment of the capability of membrane materials to remove microorganisms.

The protocol is designed for scientific rigor, but also for ease of implementation by a qualified laboratory, denoted as Laboratory Testing Organization throughout this document. The data generated from execution of the protocol is intended to provide utilities, engineers and regulators with the necessary information to make informed decisions about current and future membrane products that are being (or will be) employed for treatment of water supplies. As an option outside of ETV testing, this protocol may also be used by the manufacturer to determine the membrane lot acceptance of a membrane filtration media when challenge testing is needed to demonstrate removal for a lot acceptance.

The general approach described herein would be added to Task 8 (Microbial Removal) of the ETV Membrane Test Plan for Microbiological and Particulate Reduction (April 2002). The ETV Protocol would be modified to require microbial testing either at bench-scale or in the field.

## GENERAL APPROACH

The general approach to the membrane bench testing is to conduct microbial challenge studies under conditions that the microorganisms are most likely to penetrate the membrane using a standardized Low-Pressure Membrane Testing Unit. The primary operational variable shall be transmembrane pressure, which shall be applied under direct flow conditions. Feed water containing the selected microorganisms shall be applied continuously to the membrane for the duration of the challenge. No backwashing or recirculation shall be employed during the experimental run. The challenge studies shall be executed through a series of tasks as noted below and discussed in more detail after a discussion of the membrane testing unit experimental setup.

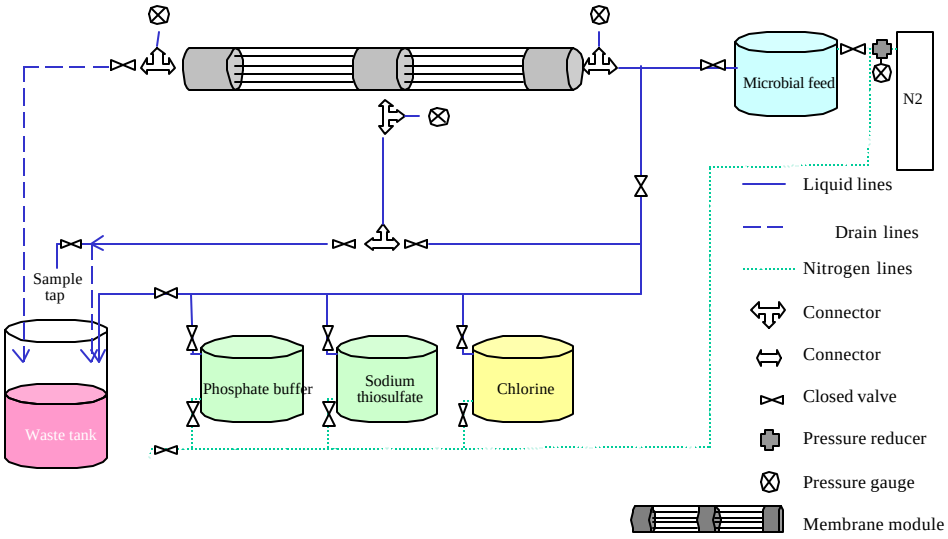
Task A – Establish Transmembrane Flux
Task B – Perform Membrane Cleaning and Backwashing
Task C – Perform Membrane Integrity Testing
Task D – Conduct Microbial Removal Experiments
Task E – Execute Data Handling Protocol

## MEMBRANE FILTRATION UNIT EXPERIMENTAL SET UP

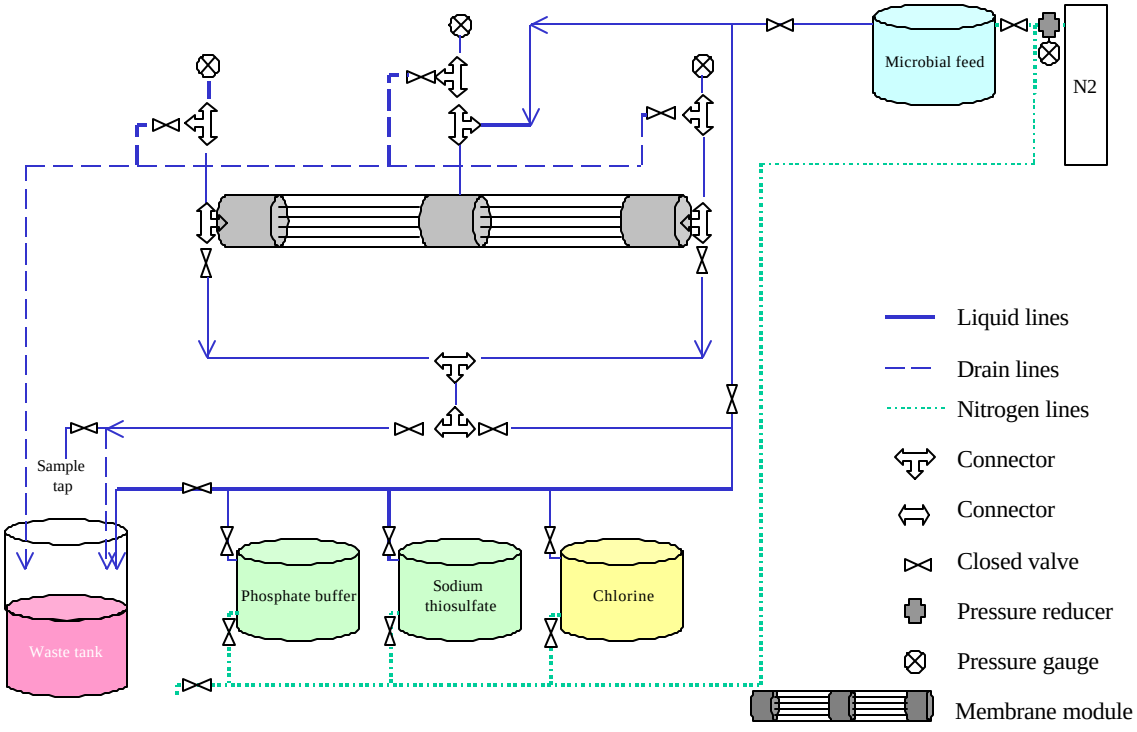
### Low-Pressure Membrane Testing Unit

The Low-Pressure Membrane Testing Unit in this document refers to the membrane module, associated tubing and connections, pressure gauges, tanks and pumps (or nitrogen tanks). The unit can be set up in three different ways, depending on the type of flow configuration necessary for the particular membrane module to be tested. These three different experimental setups for the Low-Pressure Membrane Testing Unit are illustrated in Figures 1a, 1b and 1c. The three setups accommodate two pressure-driven flow configurations (inside out and outside in) as well as one outside-in, vacuum driven configuration. The same Low Pressure Membrane Testing Unit can be employed for each flow configuration with minor tubing changes.

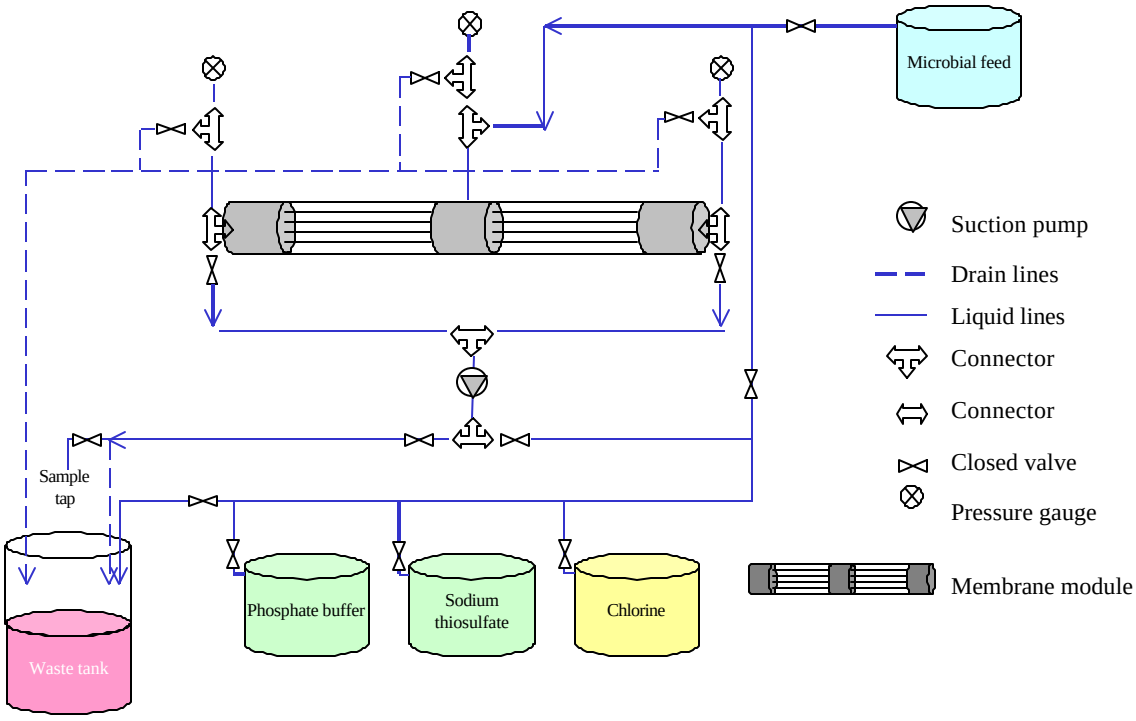
The Low-Pressure Membrane Testing Unit is comprised of five separate tanks: one tank provides a microbial feed for the challenge studies; three other tanks (chlorine or other biocidal agent, sodium thiosulfate and phosphate buffer) are employed for backwashing and/or cleaning the membrane module between experimental runs. A fifth tank is used to collect waste. Pressurized nitrogen gas is employed to provide system pressure, since mechanical pumping can cause perturbations in pressure application. A vacuum system is employed for submersible vacuum driven applications. Details of materials used for construction of the Low-Pressure Membrane Testing Unit are presented in Appendix B.




Schematic of Low-Pressure Membrane Test Unit – Inside/out flow configuration, pressure driven
Figure 1a




Schematic of low pressure membrane filtration unit – Outside/In flow configuration, pressure-driven
Figure 1b




Schematic of low pressure membrane filtration unit – Outside/in flow configuration vacuum driven
Figure 1c

**Selection of Membrane Modules for Bench-Scale Challenge Testing**

Membranes exhibit product variability, and the degree of variability will depend on a number of factors specific to the product and the manufacturing process. Furthermore, product variability is manifested in different aspects of product performance and characteristics. Membranes may exhibit variability with respect to removal efficiency, pore size distribution (nominal and absolute), bubble point, productivity, and membrane area among other characteristics. All of these aspects of product variability can be important considerations for a specific application; however, variability in removal efficiency is of primary concern in the context of challenge testing.

The membrane material used by the manufacturer to fabricate the bench modules will be obtained from full-scale modules. The membrane modules used for evaluation in the Low-Pressure Membrane Testing Unit shall be based on the statistical distribution of nondestructive performance test results, as described below, or an alternative approach provided by the manufacturer and Laboratory or Field Testing Organization. If an alternative approach is desired, it shall be reviewed and approved by NSF and the EPA under the ETV Program prior to implementation. Alternative approaches shall take into account product variability in terms of efficacy of microbial removal and may depend upon the specific characteristics of the membrane.

**Membrane Selection by Non-Destructive Membrane Test.** A nondestructive performance test is a physical test that characterizes a fundamental property of the membrane that can be correlated to some aspect of process performance, and which does not alter or damage the membrane. In the context of challenge testing, the nondestructive performance test must be correlated to the removal efficiency of the target organism. An example of such a test is the bubble point test, the results of which can be directly related to the size of the largest pore in a membrane. Manufacturers often use such nondestructive testing as a means of quality control and assurance, and in many cases such a test is applied to every production module. The results of such extensive testing can provide a good estimate of product variability as it relates to removal efficiency.

The nondestructive performance test is used to assure the removal efficiency of production modules in the following manner. The challenge test demonstrates the removal efficiency of the specific module(s) evaluated, and these modules are characterized through application of the nondestructive performance test that is used as part of the manufacturer's routine quality control and assurance program. The results of the nondestructive performance test applied to the module(s) evaluated during the challenge test establish a control limit for the nondestructive performance test. This test is applied to all production modules, which must meet or exceed the control limit established during the challenge. Membrane modules that do not meet or exceed the established control limit will not be eligible for testing. Thus, it is necessary to compare the result from the nondestructive performance test against the control limit for each module used in a system.

The nondestructive performance serves as the basis for confirming the performance of membrane modules that are not directly challenge tested. Manufacturers that have historically performed nondestructive testing for the purpose of product quality control and assurance can use this information to characterize the variability of a product line. Additionally, a manufacturer may have established a *quality control release value* for the nondestructive performance test that provides a minimum cutoff for an acceptable product. Based on these considerations, it may be prudent to select membrane modules for challenge testing based on nondestructive performance test results.

Since the challenge test is used to establish the control limit for the nondestructive performance test that production modules must meet, it would be prudent to test modules with nondestructive performance test results that are close to the quality control release value. The rational behind testing a worst-case module is that it allows for fewer modules to be tested while still providing a means of verifying the removal efficiency of production modules through application of the nondestructive performance test. This approach for module selection may be especially useful when complete removal of the challenge organism is anticipated for all modules across the range of the product line.

It should be noted that many nondestructive performance tests that are suitable for evaluating the ability of a membrane to remove large organisms, such as *Cryptosporidium*, will not apply to very small ones, such as viruses. As an example, the bubble point test cannot typically be applied at a pressure high enough to achieve a resolution on the order of the size of a virus. In such cases, other manufacturing quality control procedures would be necessary to assure virus removal capabilities of production modules. These may include internal quality control testing of the membrane media or testing for membrane module lot acceptance.

**Bench-Scale Membrane Module Requirements.** A minimum of 3 bench modules, each with materials as close to the quality control release values, shall be provided by the manufacturer. Each module shall have an effective membrane area of approximately 0.1 $m^2$, shall be employed for each bench-scale microbial characterization. If necessary, the modules may be fabricated by the Manufacturer specifically for this testing. The modules shall have an effective length similar to those employed at full scale for water treatment applications. It is recognized that the length of the bench module may be slighter shorter than that of a full-scale module if the materials to fabricate it are take from a full-scale module. Before conducting testing, the membranes shall be fully wetted according the Manufacturer's specification. After wetting, each module shall be conditioned at a typical transmembrane flux (as specified by the manufacturer) for a minimum of 8 continuous hours before any testing begins. A 0.1 mM phosphate buffer solution (pH 7.0) shall be employed as the feedwater. Specific flux shall be monitored once per hour and recorded.

## SEQUENCE OF EVENTS FOR MODULE TESTING

Table 1 below presents the general sequence of events for module testing. These events are described in more detail in each of the tasks below.

**Table 1**
**Sequence of Events for Low-Pressure Membrane Module Testing**

| Event | Comments |
|---|---|
| Conditioning period for module | Run module for 8 hours |
| Perform first membrane integrity test | Described in Task C |
| Set transmembrane flux; determine specific flux | Conduct before and after 5 HRT's; chemically clean only if necessary; described in Task A |
| Perform microbial challenge test on module | Described in Task D |
| Determine specific flux | Described in Task A |
| Perform second membrane integrity test | Described in Task C |
| Repeat same sequence with other modules | |

## TASK A: ESTABLISH TRANSMEMBRANE FLUX

### Introduction

Bench-scale membrane operation in terms of transmembrane flux will be established in this task. This task shall be conducted for each of the three membrane modules being tested. This task shall also be repeated after each chemical cleaning (see Task B), if chemical cleaning is necessary. Each repetition of this task involves filtration of 0.1 mM phosphate buffer solution for 5 hydraulic residence times of the low pressure membrane test unit's module and tubing at a transmembrane flux under which microorganisms would be most likely to penetrate the membrane.

**Experimental Objectives**

The objectives of this task are to document the operational conditions under which each of the five membrane modules will be evaluated for microbial removal and then to verify those operational conditions before and after testing of each membrane module.

**Work Plan**

**Specification of Transmembrane Flux.** For this task, the Laboratory Testing Organization shall specify the transmembrane flux to be employed during the microbial challenge studies. The microbial challenge experiments shall be conducted at operating conditions under which the microorganisms would be most likely to penetrate the membrane. These conditions shall include the highest operational flux specified by the manufacturer for their membrane under direct flow hydraulic conditions. The Laboratory Testing Organization shall clearly describe how these conditions were chosen. It is anticipated that the transmembrane flux should be constant over the time of the experiment, since it is short in duration. However, if greater than 10 percent specific flux decline of the membrane occurs after filtering 0.1 mM phosphate buffer for 5 hydraulic residence times of the low pressure membrane test unit's module and tubing, chemical cleaning shall be performed according to manufacturer specifications. Adjustments to the operational strategy shall be made (such as a decrease in transmembrane flux) as necessary. Decisions on adjustments of transmembrane flux shall be made by the Laboratory Testing Organization in consultation with the Manufacturer's experience.

Microbial challenge studies at additional operational flux conditions are at the discretion of the Manufacturer and the designated Laboratory Testing Organization. However, testing of alternate additional operational conditions shall be performed only in addition to the initial flux condition specified in the Work Plan.

**Determination of Specific Flux.** On each new module, and before and after each microbial removal experiment, the hydraulic performance of the membrane module shall be evaluated by determining its specific flux. The required parameters to calculate the specific flux include:

- filtrate flow rate,
- area of the potted membrane, and
- transmembrane pressure.

To evaluate the filtrate flow rate of the membrane, a volume of permeate is collected over a period of one minute.

The effective membrane surface area is determined as:

$$A = \pi \times (OD) \times (l) \times (n)$$

where:
A = effective membrane surface area in $m^2$ or $ft^2$,

l = the length of the module in cm or inches,
OD = outside diameter (OD) of the fibers (for an outside/in flow configuration) in mm or inches, and
n = number of fibers.

The transmembrane flux is determined empirically as:

$$J_o = \frac{Q_p}{A}$$

where:
J = transmembrane flux in L/hr/$m^2$ or gfd,
$Q_p$ = filtrate flow rate in L/hr or gal/day, and
A = effective membrane surface area in $m^2$ or $ft^2$.

In a direct filtration mode, the transmembrane pressure is calculated according to:

$$P_{tm} = P_i - P_p$$

where:
$P_{tm}$ = transmembrane pressure in bar or psi,
$P_i$ = pressure at the inlet of the module in bar or psi, and
$P_p$ = permeate pressure in bars or psi.

The water volume transfer through the membrane per unit of membrane area and driving force is the specific flux ($J_s$) as described by:

$$J_s = \frac{J}{P_{tm}}$$

where:
$J_s$ = specific flux (permeability) in L/hr/$m^2$/bar or gfd/psi.
J = transmembrane flux in L/hr/$m^2$ or gfd at 20 degrees C,
$P_{tm}$ = transmembrane pressure in bar or psi,

Dividing by the transmembrane pressure or net driving force is a method by which the transmembrane flux is normalized. Specific flux is a useful measure by which different membrane operating conditions can be compared to each other.

Temperature corrections to 20°C for transmembrane flux shall be made to correct for the variation of water viscosity with temperature. A specific, empirically derived equation developed by the membrane

manufacturer may be used to provide temperature corrections. Alternatively, the following equation by Streeter and Wiley (1985) may be employed:

$$J = \frac{Q_p \times e^{-0.0239 \times (T-20)}}{A}$$

where:
J = instantaneous flux in L/hr/$m^2$ or gfd,
$Q_p$ = filtrate flow rate in L/hr or gal/day,
T = temperature in $^oC$, and
A = effective membrane surface area in $m^2$ or $ft^2$.

**Evaluation Criteria and Minimum Reporting Requirements**

- Bar graph of specific flux normalized to 20$^o$C before and after challenge testing of each module.

## TASK B: ASSESS CLEANING EFFICIENCY AND BACKWASHING

**Introduction**

Although not anticipated, chemical cleaning of the membrane may be necessary. Cleaning chemicals and cleaning routines shall be based on the recommendations of the Manufacturer. The Manufacturer and their designated Laboratory Testing Organization shall specify in detail the procedure(s) for chemical cleaning of the membranes. At a minimum, the following shall be specified:

- cleaning chemicals
- hydraulic conditions of cleaning (flow, transmembrane pressure)
- duration of each cleaning step
- initial and final temperatures of chemical cleaning solution

**Evaluation Criteria and Minimum Reporting Requirements**

At the conclusion of each chemical cleaning and upon return to membrane operation, the initial condition of transmembrane pressure, flow and temperature shall be recorded and the specific flux calculated. The efficacy of chemical cleaning shall be evaluated by the recovery of specific flux.

- Bar graph of specific flux normalized to 20$^o$C after each chemical cleaning.

## TASK C: PERFORM MEMBRANE INTEGRITY TESTING

### Introduction

Monitoring of membrane integrity is necessary to ensure that an adequate barrier is continuously being provided by the membrane material during the challenge testing. Only direct membrane integrity monitoring shall be employed in the bench-scale testing. Examples of direct monitoring methods include, but are not limited to:

- air pressure decay testing,
- diffusive air flow testing,
- bubble point testing,
- sonic wave sensing.

A brief overview of these direct monitoring methods is provided below.

*Air Pressure Decay Test (PDT):* In this test, the membrane module is pressurized to approximately 15 psi. Minimal loss of the held pressure (generally less than 1 psi every 5 minutes) at the filtrate side indicates a passed test, while a significant decrease of the held pressure indicates a failed test.

*Diffusive Air Flow Test:* The diffusive air flow test uses the same concept as the air pressure-hold test, but is performed by monitoring the displaced liquid volume due to the leaking air from compromised fiber(s). This test is more sensitive than the air pressure test because it is technically easier and more accurate to measure small variations in liquid volume rather than small variations in air pressure.

*Bubble Point Test:* Bubble point testing can identify the fiber or seal location that is compromised in a membrane module. The test is typically performed after the compromised module is identified by a sonic sensor or any other monitoring method. After identifying the compromised fiber, it can be isolated from the module by adding an epoxy glue to its inlet, or by inserting pins of the same diameter as the fiber at the fiber inlet and outlet edges.

*Sonic Sensing:* Sonic sensor equipment consists of a sound wave sensor attached to a headphone. The headphones are manually placed at the top, middle, and bottom of the membrane module during the air-pressure hold test to detect any sound waves created by potential air bubbles leaking through a damaged fiber. The difference in sound between an intact and a compromised membrane may be identified by the pilot operators. Sonic sensing is only a qualitative tool for detecting loss of membrane fiber integrity, and therefore this test must be followed by a more quantitative method for evaluation of membrane integrity.

### Experimental Objectives

The objective of this task is to demonstrate the methodology to be employed for monitoring membrane integrity and to verify integrity of membrane modules.

**Work Plan**

The Laboratory Testing Organization shall clearly describe the most appropriate methods for monitoring of membrane integrity at bench scale. The techniques listed above are intended to serve as examples of direct methods for monitoring membrane integrity. These direct monitoring methods shall provide sensitive evaluation of membrane system integrity. It should be noted that pilot and/or full-scale methods of membrane integrity testing might have to be adapted for bench-scale applicability. If the membrane module is shown to be compromised by integrity testing, it shall be discarded and another module shall be provided as a replacement.

Integrity testing shall be performed before and after challenge testing of each module. Since pressure decay tests (PDTs) are often used to measure membrane integrity, an example of adapting pilot integrity methodology to bench scale is described below.

PDTs are performed on each module before and after all challenge testing is completed for that module in order to assure the membrane module being evaluated is not compromised. To perform the test, the membrane fibers are emptied of feed solution by applying pressure from a nitrogen tank to the inner lumen of the fibers at the both ends of the modules (it is important, however, to keep the membrane fibers wetted). Nitrogen air feed pressure is set at 15 psi, after which the pressure feed line is closed. Then, the pressures at the inlet and outlet of the modules are monitored and recorded at a frequency of not less than one minute for a period of 15 minutes. If the module is intact, only a small decrease in pressure is observed (usually less than 1 percent over a period of 15 minutes). If the membrane material or module is compromised, the PDT will show a substantial decrease of pressure over time. Figure 2 shows PDT data on both intact and compromised modules using a Low Pressure Membrane Testing Unit.

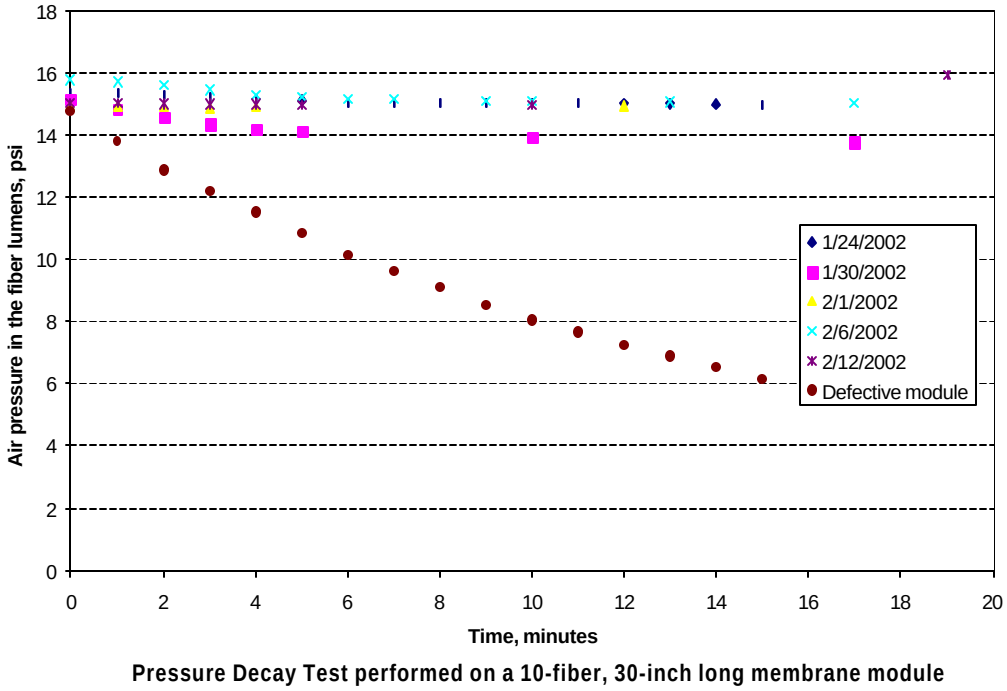



Figure 2

**Evaluation Criteria and Minimum Reporting Requirements**

- Table of membrane integrity results as appropriate.
- Graph of integrity test results over time where appropriate for selected methodology.

## TASK D: CONDUCT MICROBIAL CHALLENGE EXPERIMENTS

**Introduction**

In this task, the effectiveness of membrane materials for microbial removal shall be evaluated by use of microbial challenge studies.

**Experimental Objectives**

The objective of this task is to characterize the low-pressure membranes in terms of microbial removal.

**Work Plan**

The Laboratory Testing Organization shall conduct the microbial seeding studies as described in the sections below.

**Organisms Employed for Bench-Scale Challenge Experiments.** Table 2 presents the different microorganisms that may be employed for the bench-scale microbial challenge studies. Two protozoan cysts, two bacteria and four viruses can be used for the challenge studies. These organisms were chosen to provide a wide range in types and sizes of microorganisms in order to create a microbial removal profile for the low-pressure membrane being challenged. The list of microorganisms in Table 2 is not a complete list and other microorganisms may be proposed for use, as circumstances require.

**Table 2**
**Microorganisms for Microbial Challenges of Low-Pressure Membranes***

| Type of Microorganism | Microorganism | Approximate size, microns |
|---|---|---|
| Protozoa | *Cryptosporidium parvum* | 3-5 |
| Bacteria | *Escherichia coli* | 1-10 |
| | *Pseudomonas diminuta* | 0.6 –1 |
| Virus | MS2 bacteriophage | 0.027 |
| | PRD1 bacteriophage | 0.070 |
| | hepatitis A virus | 0.025 |
| | calicivirus | 0.025 |

* The list of microorganisms in Table 2 is not a complete list and other microorganisms may be proposed for use as circumstances require.

It is recognized that, in many cases, it may not be possible to employ viable protozoan cysts and oocysts for challenge studies, depending upon the laboratory where the work is being performed. In such a case, the organisms shall be heat-fixed. Organism stocks received from appropriate suppliers shall be stored under refrigeration in the dark at 4°C or frozen (viruses only) with appropriate preservatives until use in the challenge studies. Methods for propagation and enumeration of Table 2 organisms are described or reference in Appendix A.

**Disinfection of Experimental System.** Before performing microbial challenge experiments, the membrane module and tubing associate with the bench-scale Low-Pressure Membrane Testing Unit shall be disinfected using a 50 mg/L free chlorine solution (or other appropriate biocidal agent), which is prepared in a pressurized feed tank. The pressure in the tank shall be set at 15 psi and the membrane unit shall be operated in a backwash mode.

The membrane module and associated tubing shall be backwashed for a minimum of three hydraulic cycles with the disinfecting solution. The module and associated tubing shall then be rinsed with a 3-molar excess sodium thiosulfate solution (or other appropriate chemical) to assure any residual chlorine is quenched. The membrane module shall then be rinsed in backwash mode at 15 psi for an additional three hydraulic cycles with a 0.1 mM phosphate buffer (pH 7.0).

**Microbial Challenge Experiments**

The microbial challenge experiments shall be conducted under the operating conditions in which the microorganisms would be most likely to penetrate the membrane. These conditions shall include the highest operational flux specified by the Manufacturer for their membrane. All challenge tests shall be conducted as batch seeding tests under direct flow hydraulic conditions. The challenge testing shall be conducted for all organisms simultaneously, i.e., all organisms shall be seeded into the feedwater prior to the conduct of the testing. For each module tested, four samples shall be collected: two discrete seeded feed tank samples (at the beginning and at end of the each test) and two discrete filtrate samples (samples may be collected sequentially, one right after the other). Thus, for the three modules evaluated, a total of 12 samples shall be collected.

Feedwater to which microorganisms shall be added shall consist of a 0.1 M phosphate buffer (pH 7.0) prepared from distilled, deionized laboratory water. To check the quality of the water, measurements of pH, turbidity, particle counts, and conductivity shall be made and recorded before the seeding of any organisms. Additionally, the total organic carbon to dissolved organic carbon ratio shall be less than 0.1 mg/L. Feedwater turbidity shall not exceed 0.1 NTU. Particle counts in the 2 – 50 µm size range shall not exceed 25 per mL. Methods for these analyses are described in Appendix A.

The feed suspension of microorganisms shall be prepared by adding the concentrated stock suspension(s) of organisms into the feedwater reservoir. For organisms that are propagated at very high titers (for MS2 and PRD1, the initial stock densities are approximately $10^{11}$ - $10^{12}$ plaque forming units/mL), one or more dilutions shall be made before adding the organisms to the feedwater tank. This tank shall be completely mixed during preparation of the seeded feedwater. Sufficient volume of stock suspension shall be created to sustain membrane operation for a minimum of 5 hydraulic retention times per membrane module per experimental challenge test. After the addition of challenge organism(s) to the feedwater tank and before the initiation of filtration, one sample shall be collected from the feedwater tank to establish the initial titer of the microorganisms. For the protozoa challenge tests, the final seeding concentration in the feedwater tank shall be high enough to provide a microbial removal sensitivity limit of at least 4 logs. For the bacterial and virus challenge tests, the final seeding concentration in the feed water tank shall also be high enough to provide a microbial removal sensitivity limit of at least 5 logs.

At the beginning of the microbial challenge test (before seeding the organisms into the feedwater tank), the hydraulic run conditions (transmembrane pressure and flux) shall be established under Task A. The feed suspension of microorganisms shall be filtered under these conditions for a total of five hydraulic residence times in order to achieve steady state. At the end of this period, two discrete, consecutive samples shall be collected. Each sample shall consist of collecting 35 mL of filtrate in a sterile, 50 mL polypropylene centrifuge tube (polypropylene is employed to avoid adsorption of the microorganisms onto the walls of tube). At the conclusion of testing each module, a second sample shall be collected from the feedwater tank. All samples shall be stored at 4°C immediately after collection. The geometric mean of the "before" and "after" feedwater tank microbial densities shall be used when calculating microbial removal efficacies.

Before beginning the testing of the next previously-conditioned membrane module, the module and tubing shall be backwashed with 50 mg/L of free chorine (or other appropriate biocidal agent) for five hydraulic cycles. The membrane shall then be rinsed with a 3-molar excess sodium thiosulfate solution (or other appropriate chemical) buffer and phosphate buffer as described above. After this procedure, the next test shall be initiated. At the end of each day, the microbial samples shall be shipped via overnight express for enumeration, if not enumerated on site.

**Operational Data Collection**

Operational data is collected under Task A.

**Evaluation Criteria and Minimum Reporting Requirements**

- Table of water quality data: pH, turbidity, particle counts, and conductivity
- Table of feed water and filtrate levels for all organisms
- Bar chart of log removal of microorganisms

## TASK E: EXECUTE DATA HANDLING PROTOCOL

**Introduction**

The data management system used in the bench-scale membrane characterization shall involve the use of computer spreadsheets and manual recording of operational parameters for the Low-Pressure Membrane Test Unit.

**Experimental Objectives**

The objective of this task is to establish a structure for the recording and transmission of laboratory testing data.

**Work Plan**

The following protocol has been developed for data handling and data verification by the Laboratory Testing Organization. Specific parcels of the computer databases for operational and water quality parameters shall be entered by manual importation into Excel (or similar spreadsheet software). Backup of the computer databases to diskette shall be performed at the end of each day.

Measurements shall be recorded on specially prepared data log sheets as appropriate. A laboratory notebook shall be used to record all data, calculations and other pertinent information not included in the data log sheets. The laboratory notebook shall provide carbon copies of each page. The original notebooks shall be stored in the laboratory.

The database for the project shall be set up in the form of custom-designed spreadsheets. The spreadsheets shall be capable of storing and manipulating each monitored water quality and operational parameter from each task, each sampling location, and each sampling time. All data from the laboratory notebooks and data log sheets shall be entered into the appropriate spreadsheet. All recorded calculations shall also be checked at this time. Following data entry, the spreadsheet shall be printed out and the printout shall be checked against the handwritten data sheet. Any corrections shall be noted on the hard copies and corrected on the screen, and then a corrected version of the spreadsheet shall be printed out. Each step of the verification process shall be initialed by the bench testing operator, technician or engineer performing the entry or verification step.

The testing of each membrane module shall be assigned a run number that will then be tied to the data from that experiment through each step of data entry and analysis. As samples are collected, the data shall be tracked by use of the same system of run numbers. Data from the outside laboratories, if any, shall be received and reviewed by the laboratory staff conducting the studies. These data shall be entered into the data spreadsheets, corrected, and verified in the same manner as the field data.

## REPORT MEMBRANE PORE SIZE TASK

### Introduction

It is proposed that by the addition of the bench-scale laboratory microbial challenge tests, the task of reporting the membrane pore size will be changed from a required task to suggested information that the vendor would supply for their equipment description. This data will be provided for informational purposes only and will not be verified by the ETV Program. While it is best to characterize membranes microbially, it is still useful to compare the manufacturer's membrane pore size distribution with the measured membrane microbial removal from Task D. Low-pressure membrane manufacturers report a "nominal" pore size, a size above which a specified percentage of particles of a certain nature are rejected under select conditions.

### Experimental Objectives

The objective of this task is to report the 90 percent and maximum pore size for the membrane tested. This is a suggested task.

### Work Plan

Membrane Manufacturers will have determined the pore size distribution for their membranes. The 90 percent and maximum pore size should be reported and the general methods used for determining the values should be discussed.

**REFERENCES**

APHA, AWWA, WEF. 1999. Standard Methods for the Examination of Water and Wastewater, 20th Ed. American Public Health Association, Washington, D.C.

ASTM Method F838-83 (Reapproved 1993) Standard Test Method for Determining Bacterial Retention of Membrane Filters Utilized for Liquid Filtration.

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Streeter, V.L. and E.B. Wiley. 1985. Fluid Mechanics, 8th ed. New York, McGraw Hill Book Company.

U.S. Environmental Protection Agency. 1999. Method 1623: *Cryptosporidium* and *Giardia* in water by filtration, immunomagnetic separation, and fluorescent antibody. Publication EPA-821-R-99-006. Office of Water, Washington, D.C.

## APPENDIX A: QUALITY ASSURANCE/QUALITY CONTROL

### Introduction

Quality assurance and quality control of the operation of the membrane equipment and the measured water quality parameters shall be maintained during the laboratory testing program.

### Operational and Low-Pressure Membrane Testing Unit QA/QC

Before the testing of each manufacturer's modules, on-line pressure gauges shall be checked with secondary gauges to confirm that the readout matches the actual measurement. Unit tubing and connections shall be inspected weekly to verify that they are in good condition. Replacement of these materials shall be made as necessary.

### Analytical Methods

The analytical methods utilized in this study for feedwaters are described in the section below.

**pH**. Analyses for pH shall be performed according to Standard Method 4500-$H^+$. A 3-point calibration of the pH meter used in this study shall be performed once per day when the instrument is in use. Certified pH buffers in the expected range shall be used. The pH probe shall be stored in the appropriate solution defined in the instrument manual.

**Temperature**. Readings for temperature shall be conducted in accordance with Standard Method 2550. The thermometer shall have a scale marked for every 0.1°C, as a minimum, and shall be calibrated biweekly against a precision thermometer certified by the National Institute of Standards and Technology (NIST). (A thermometer having a range of –1°C to +51°C, subdivided in 0.1°C increments, would be appropriate for this work.)

**Turbidity Analysis**. Turbidity analyses shall be performed according to Standard Method 2130 or EPA Method 180.1 using a bench-top turbidimeter. All glassware used for turbidity measurements shall be cleaned and handled using lint-free tissues to prevent scratching. Sample vials shall be stored inverted to prevent deposits from forming on the bottom surface of the cell. Grab samples shall be analyzed using a bench-top turbidimeter. The bench-top turbidimeter shall be calibrated within the expected range of sample measurements at the beginning of the laboratory-testing program using primary turbidity standards of 0.1, 0.5, and 3.0 NTU. Secondary turbidity standards shall be obtained and checked against the primary standards. Secondary standards shall be used on a daily basis to verify calibration of the turbidimeter. Further information on calibration, verification of calibration, sampling and analysis can be found in the *ETV Protocol for Equipment Testing for Physical Removal of Microbiological and Particulate Contaminants* (NSF/USEPA, 2002).

**Particle Counting.** Bench-top particle counters shall be used to measure particle concentrations in the feedwater. Laser light scattering or light blocking instruments are recommended for particle counting. However, other types of counters such as Coulter counters or Elzone counters may be considered.

The following particle size ranges (as recommended by an AWWARF Task Force) shall be monitored by bench-top analytical instruments during the membrane characterization testing:

- 2-3 µm
- 3-5 µm
- 5-7 µm
- 7-10 µm
- 10-15 µm
- >15 µm

Information on calibration, verification of calibration, maintenance of the particle counters, particle free water, sampling and analysis can be found in the *ETV Protocol for Equipment Testing for Physical Removal of Microbiological and Particulate Contaminants* (NSF/USEPA, 2002).

**Conductivity.** This parameter shall be measured according to Standard Method 2510B (1998).

**Total Organic Carbon (TOC) /Dissolved Organic Carbon (DOC).** TOC/DOC shall be analyzed according to Standard Method 5310B or 5310C (1998).

**Chlorine Preparation for Membrane Cleaning.** The stock solution shall be prepared by adding an estimated volume of 6% reagent-grade NaOCl into a 500-mL, chlorine demand free, bottle containing an estimated amount of organic-free water. The chlorine stock solution shall be at least 50 times stronger than the chlorine dose required. Refer to Standard Method 4500-Cl F for the preparation method of DPD indicator, FAS standard and buffer solution. Residual free chlorine measurements will be conducted according to *Standard Methods* 4500-Cl G. DPD Colorimetric Method.

**Bacteriophages.** Bacteriophages MS2 and PRD1 shall be enumerated according to National Water Research Institute and American Water Works Association Research Foundation, 2000. Because of the importance of this organism in characterizing the membrane at bench scale, detailed methods for MS2 are provided below and shall be followed.

*MS2 bacteriophage Soft Agar Overlay Method and MS2 Stock Preparation.* The bacteriophage MS2 – ATCC 15597-B1 shall be employed in all studies. The *Escherichia coli* C-3000 – ATCC 15597 shall be employed as the host bacterium, with the bacterial growth media being tryptic soy broth (TSB) – DIFCO 0370-15-5, or the equivalent.

*Tryptic Soy Agar (bottom agar petri plates 100 x 15mm) Preparation.* The media is rehydrated according to label directions. A magnetic stir bar is placed into the dehydration flask, and the media is brought to a near boil to dissolve the agar. The flask and contents are then sterilized by autoclaving for 15

minutes after which it is cooled in a water bath to between 45-50$^0$C. Plates are poured using approximately 12–15 mL per plate. Enough agar is added to cover about 2/3 of the area of the plate. After pouring one plate, the lid is replaced on the dish and gently swirled so that the agar covers the entire bottom of the plate. Plates are allowed to remain motionless until the agar hardens (usually 10-15 minutes). Plates are stored at 4$^0$C up to 30 days.

*Tryptic Soy Agar Overlay Tubes.* The media is rehydrated according to label directions. A magnetic stir bar is placed into the rehydration flask, and the media is brought to a near boil to dissolve the agar. The media is sterilized for 15 minutes and then pipeted aseptically into 15 mL tubes (3mL per tube) or pipeted into the tubes (3 mL per tube), which are then capped loosely and sterilized for 15 minutes. The caps are tightened after cooling. Overlay tubes are stored at 4$^0$C for 30 days.

*Preparation of High-Titer MS2 Bacteriophage.* To propagate the MS2 bacteriophage, a bacterial host slant of *E. coli* (ATCC #15597) is washed with 3 mL of sterile TSB. The total 3 mL is then transferred to a 1-liter flask containing 200 mL of sterile TSB and incubated at 37$^0$C for approximately 3 hours. At this time, the flask is removed from the incubator and 2 mL of bacteriophage stock (ATCC #15597-B1) is added and then the flask is placed back in the incubator for an additional 4 hours. Then, 0.02 g of lysozyme and 6 mL of 0.2 M sterile EDTA are added to the flask which is shaken for an additional 30 minutes. The bacteriophage/bacteria suspension is poured into 4-50mL centrifuge tubes and centrifuge at 4,000 times gravity for 15 minutes.

During preparation of high titer MS2 bacteriophage stocks, there is a potential for aggregate formation. To reduce aggregates, the MS2 stock is filtered through sequentially smaller (0.45 micron, 0.22 micron and 0.1 micron), low protein-binding filters. To reduce MS2 binding to the filter, each filter is pretreated by filtering 10 mL of 0.1% Tween 80 followed by 10 mL reagent grade non-chlorinated water. MS2 stock preparations are filtered through these pretreated filters with careful attention focused on amount of pressure/vacuum applied to prevent membrane filter failure. Multiple filters may be necessary to filter the entire MS2 stock solution.

The bacteriophage stock is then titered to determine its concentration and stored at 4$^0$C for up to 4 weeks.

*Preparation of Host Culture.* The host culture is started the day before the assay is to be performed. Using a sterile swab, a small amount of *E. coli* host (ATCC 15597) is removed from an agar slant and placed into a sterile tube containing 3 mL of tryptic soy broth and grown overnight at 37$^0$C for 24 hours. The next day, 1 mL of the overnight culture is pipeted into 50 mL of tryptic soy broth in a 250 mL Erlenmeyer flask or the equivalent. The culture is then placed in a 37$^0$C incubator for 4 hours, after which it is removed from incubator and place on ice until used.

*Soft Agar Overlay Method for Bacteriophage.* Bacteriophage in bench-scale low pressure membrane samples are enumerated by the addition of the sample to soft or overlay agar along with a liquid culture of bacteria (host) in the log phase of growth. Overlay tubes are melted in a boiling water bath or autoclaved for 5 minutes and place in a 49$^0$C water bath until used. The bottom of the petri plates are labeled with the identification of sample to be analyzed. Then 0.1 – 1 mL of the 4-hour host culture (which is in log phase of

growth) is pipeted into a prewarmed overlay tube along with 0.1 –1 mL of the sample to be analyzed. The tube is mixed by rapidly rolling between the analyst's palms and pour onto a TSA plate. The sample is spread evenly over the surface of the plate by gently and quickly swirling the plate. The plate, which solidifies within 30 seconds, is then inverted and incubated at $37^0$C for 24 hours +/- 2 hours. The sample is then incubated for 24 hours. During the incubation time, the host bacteria forms a confluent lawn over the surface of the petri plate. The petri plate is incubated at $37^0$C for 24 hours. During the incubation period, the phage particles that are present in the sample attach to and infiltrate the bacterial host cells. The bateriophages replicate within the bacterial cells and reach a concentration that lyse (burst) the bacterium. The destruction of the bacterial cells that make up the confluent lawn result in clear areas known as plaques. The concentration of bacteriophage originally present in the sample are determined by visually counting the clear areas, which are reported number of plaque forming units per mL (PFU/mL).

***Giardia sp.*** **and** ***Cryptosporidium sp.*** These organisms shall be enumerated according to U.S. Environmental Protection Agency Method 1623 (1999).

***Pseudomonas diminuta.*** This organism shall be enumerated according to ASTM Method F838-83 (1993).

***Escherichia coli.*** This organism shall be enumerated according APHA, AWWA, and WPCF (1999).

## APPENDIX B: MATERIALS EMPLOYED FOR FABRICATION OF BENCH SCALE LOW-PRESSURE MEMBRANE TEST UNIT

(Note: if needed, contact NSF for potential source of materials.)

Two-gallon pressure vessels with vacuum closure (2 gallons volume)

- Glass-filled nylon instant tube fitting, male pipe adapters ¼'', ¼''
- Glass-filled nylon instant tube fitting, male 90 elbow pipe adapters ¼'', ¼''
- Glass-filled nylon instant tube fitting, male branch tee pipe adapters ¼'', ¼''
- Glass-filled nylon instant tube fitting, male run tee pipe adapters ¼'', ¼''
- Glass-filled nylon instant tube fitting, coupling ¼'', ref 5779k14
- Glass-filled nylon instant tube fitting, 90 elbow ¼'', ref 5779k24
- Glass-filled nylon instant tube fitting, tee ¼'', ref 5779k34
- Cement: All-purpose cement for PVC, ABS, CPVC and reference 30821
- Nylon tubing: named "Nylon 6 tubing" and order in ¼'' OD, ref 5173K9
- PVC threaded pipe fitting – schedule 80 – dark gray, reducing hex bushing, NPT male ¾' x NPT female ½', ref 4596k414
- Miniature chrome-plated brass ball valves, female ¼'', female ¼'', wedge handle, ref 4912k47
- Teflon thread sealant tape, ½' width, ref 4591k12

# BENCH-SCALE PROTOCOL
# REVIEW COMMENTS RECEIVED FROM STAKEHOLDERS

**STATES AND ASSOCIATIONS THAT AGREE WITH THE PROPOSED APPROACH:**

Alaska Department of Environmental Conservation
Louisiana Department of Health and Hospitals, Safe Drinking Water
Utah Department of Environmental Quality
Virginia Department of Health, Division of Drinking Water
Commonwealth of the Northern Mariana Islands (CNMI, US Commonwealth)
National Rural Water Association

**STATES THAT AGREE WITH THE PROPOSED APPROACH WITH COMMENTS:**

Comments from Mr. Rick Sakaji, California Department of Health Services, October 3, 2002

Comments on "Proposed Modifications to ETV Protocol for Equipment Verification Testing for Physical Removal of Microbiological and Particulate Contaminants, Test Plan for Membrane Filtration"

We appreciate the opportunity to provide comment and feedback on the proposed modifications to the Physical Removal Microbiological and Particulate Contaminant ETV protocol. We also appreciate the difficulties you encounter trying to reach a concensus among the various stakeholders involved in the development of these protocols.

The ballot submitted has been marked as "agreeing with your proposed approach, with additional comment" in order to further the development of this protocol. However, it will be our position that the bench testing proposed in your ETV testing will not be adequate to allow a membrane technology acceptance as an alternative filtration technology in California without additional testing. We will continue to accept the data developed under the bench-scale testing program, but will require pilot studies on full-scale modules, as has been conducted previously before accepting a low pressure membrane technology as an alternative filtration technology.

The current protocols also test the membrane modules as designed and built for actual field installation. This means the integrity of the seals, seats, valves, and the other components is also tested. As currently written the bench testing allowed in these modifications does not require testing of the full-scale membrane module. Consequently, additional testing would need to be conducted in California before granting conditional acceptance as an alternative filtration technology.

Your program has provided valuable assistance to our program because of the protocols that have been established and referred to in our discussions with membrane manufacturers. If bench scale testing is amended to the existing protocols we recommend a note in the introduction stating that such testing may not be adequate to gain acceptance in a number of states.

We think that leaving the choice regarding the degree of testing in the hands of manufacturer is acceptable, as long as they understand the ramifications of their choices.

Additional questions and comments:
How will the "quality control release value" be determined ($6\sigma$ or $3\sigma$? Need standardized test procedures or the agencies accepting this technology will not have the means to conduct "fair" comparisons between the manufacturers.

Is there a standard bubble point test? Without one the values will be meaningless and noncomparable.

How close to the Quality Control Release Point are the membrane modules selected from?

The tests will be conducted under minimal flux and TMP ranges. Traditionally, when alternative technology is installed in the field, it is not allowed to operate outside the flux or TMP range under which testing was conducted.

On pg. 7 the second bullet lists the "area of the potted membrane," I think is actually the exposed membrane surface area. The potted membrane is the region that is filled with epoxy and should be impenetrable.

Also on pg. 7 one needs to the consider the area perpendicular to the direction of flow, i.e., is the flow through the membrane from the inside out or from the outside in. This affects the surface used to determine the flux.

Under Task C membrane integrity will be checked. While this provides us with assurance that the bench module is an integral unit, it does not provide us with an evaluation of the sensitivity of the method chosen to determine membrane integrity. Will the results be comparable? How will the sensitivity (Figure two shows example results from a 10 fiber module (30-in in length) scale to the full-scale units?

Table 2 should contain ATCC numbers for the microorganisms to ensure consistency between testing results. How does one ensure that the organisms exist in a homogenous monodisperse solution? With the exception of MS2 phage preparation, none of the procedures for the other microorganisms contains steps to ensure this.

The challenge is also conducted by placing all the microorganisms together. Some clumping may occur. Especially with the *E. coli* and MS2. Remember MS2 is grown up on an *E. coli* host, so attachment and loss of the MS2 may be due to attachment.

One of the challenges should check for adsorption losses by removing the membrane and checking for removal or decrease in pathogen concentrations.
Can polystyrene latex spheres be used to simulate *Cryptosporidium* or *Giardia* removal? Need standards and standard handling procedures for these.

What are the method detection limits for the biological assays? The microbial removal sensitivity is defined, but this requires an influent and effluent concentration. What is the lower limit of detection that one could reliably detect, this defines how low a concentration value can go and still be a meaningful result.

In your references the "NWRI" UV disinfection guidelines should be the "NWRI/AWWARF" UV disinfection guidelines.

The enumeration procedures for *Giardia*, *Cryptosporidium*, and *P. diminuta* are listed, but the propagation and seed preparation steps are not.

Once again, thank you for the opportunity to provide comments on the proposed revisions. We have no major objections to the concept of adding the bench testing, but the results from the testing, will not be sufficient to grant conditional acceptance as an alternative filtration technology.

## Comments from Mr. Jack Schulze, PE, for James (Red) Weddell, Texas Commission on Environmental Quality, October 18, 2002

Comments on Proposed Modifications to ***ETV Protocol for Equipment Verification . . . Membrane Filtration***

**Page 5, Membrane Selection by . . .**
There is an extensive discussion about correlating the results of the challenge study with those of direct physical integrity tests. In paragraph 2 of this discussion, you state that:

> "Membranes modules that do not meet or exceed the established control limit will not be eligible for testing."

However, the protocol does not currently require the manufacturer to provide the control limit for their modules.

Furthermore, paragraph 2 also states that:

> " The results of the nondestructive performance tests applies to the module(s) evaluated during the challenge study establish a control limit for the nondestructive performance test."

and paragraph 3 states that:

> "Since the challenge study test is used to establish the control limit for nondestructive performance testing that production modules must meet, . . ."

Thus, even if the manufacturer does supply a control limit for their full-scale modules, the document implies that a new, more stringent limit will be imposed if the bench-scale evaluation modules significantly exceed the manufacturer's minimum specifications.

Since the **Bench-Scale Membrane Module Requirements** section on page 6 state that:

> "Each module shall have an effective membrane area of approximately 0.1 $m^2$, . . ."

it is clear that the module used for the study will not be a full-scale unit and will manufactured solely for the purpose of the challenge study.

If the challenge study is going to establish a minimum control criteria for full-scale modules, the protocol should state the bench-scale module must be constructed so that its control parameters fall within a specific range of that for the production modules.

**Page 6, Bench-Scale Membrane . . .**
There are several typos in this paragraph. For example"

I. the sentence that begins " Each module shall . . ." appears to be grammatically incorrect.
II. in the sentence that begins "It is recognized . . .", the word "take" should be "taken."
III. the last four sentences that begin "Before conducting testing, . . ." appear to be more related to testing conditions than membrane requirements. This is especially true for the last two (or maybe three) sentences in the paragraph.

**Page 7, Specification of Transmembrane . . .**
The last sentence in the paragraph should end with ". . . with the manufacturer." rather than with ". . . with the Manufacturer's experience."

**Page 9, (TASK A's) Evaluation Criteria and . . .**
The bulleted item should read:

> "Bar graph of specific flux normalized to 20$^{o}$C before and after preconditioning for 5 HRTs and before and after challenge testing of each module."

**Page 9, (TASK B's) Evaluation Criteria and . . .**
If the phrase "At the conclusion of each chemical cleaning" and the phrase "upon return to membrane operation" mean the same thing, then one should be eliminated. If they do not describe the same event, then clarification is needed.

The bulleted item should read:

"Bar graph of specific flux normalized to 20$^{o}$C before and after each chemical cleaning."

and an additional item should be added if the preceding paragraph is describing different events. Furthermore, the first paragraph requires that more data be recorded than is reported.

**Page 10, Introduction**
The section entitled "*Sonic Sensing*" should be titled "*Sonic Wave Sensing*" so that it conforms with the bulleted list at the beginning of the Introduction.

**Page 11, Work Plan**
There seems to be a minor formatting problem in the paragraph containing the sentence that begins "Nitrogen air feed . . ."

**Page 12, Evaluation Criteria and . . .**
The bulleted items should read:

I. "Table of data for the membrane integrity tests conducted before and after challenge studies.
II. Where appropriate for the selected methodology, a graph of the integrity test results versus time for the tests conducted before and after challenge studies."

**Page 13, Table 2**
There is only one protozoan listed although the preceding paragraph indicates that two protozoan organisms are required. It appears that *Giardia lamblia* was inadvertently omitted from the table.

**Page 14, Microbial Challenge Experiments**
In the second paragraph, you establish a limit on the TOC:DOC ratio but not on the TOC or DOC levels; was this intentional? Is there no upper limit on either individual parameter?

Should the last sentence in the second paragraph read:

"Total particle counts in the 2–50 m size range . . ."

In order to maintain grammatical consistency the last two sentences in the third paragraph should read:

"For the protozoan challenge tests, the final seeding . . . least 4 logs. For the bacterial and viral challenge tests . . ."

**Page 15, Operational Data Collection**
Although the section references the operational data collected under Task A, that task does not include any description of operational data.

**Page 15, Evaluation Criteria and . . .**
What is the frequency that the specified data must be collected.

**Page 15, Work Plan**
The laboratory should also be allowed to back the data up to a CD, magnetic tape, or other archival format.

**Page 18, Turbidity Analysis**
The laboratory should be allowed to verify the continued accuracy of the turbidimeter using either primary or secondary standards.

**Page 19, Chlorine Preparation for . . .**

I'm not sure that I understand the purpose of making the chlorine stock solution 50 times stronger than needed to achieve the desired dose; why can't it be 25 times stronger and just double the feed rate of the stock when it is applied to the membrane feedwater stream?

## STATES THAT DO NOT AGREE WITH THE PROPOSED APPROACH WITH COMMENT:

Comments from Ms. Vicki Ray, Kentucky Drinking Water Branch, September 25, 2002

Please see following comment from staff. KY will continue to require pilot studies for membrane filtration. It is critical and essential to know how membranes are going to function with the water they are actually supposed to treat! NOT distilled water.

This looks like another case of the EPA or NSF bowing to manufacturers. It is a way to make certification of membranes a laboratory function rather than a pilot plant under actual conditions function. The test are to be used with distilled water only. How often do we find distilled water in our surface waters. The contention is that hardness and organics could foul the membranes and screw up the tests in the field under actual conditions-DUH. I would strongly oppose this change in the protocol as we already have too many programs that were formulated on laboratory studies rather than real world conditions.

## COMMENTS FROM STAKEHOLDERS

Comments from Mr. Jim Larsen, Separmatic Fluid Systems, September 25, 2002

I am responding to the request for comment regarding the proposed protocol modifications.

First, Did the proposal consider evaluation of the membrane modules in the same manner that cartridge modules are considered? The proposed protocol evaluates three membrane modules, but does not specify their origin. In the ETV cartridge protocol, three cartridges from one lot and one cartridge from three lots are evaluated to estabalish consistency of performance. I think the same standard should be applied to membranes.

Second, the justification for the proposed modification could be applied to other filtration technologies, e.g. pre-coat filtration, for the same reasons. Would not the work of Dr. Jerry Ongerth, published in the December 1997 and December 2000 issues of the Journal AWWA constitute adequate benchscale evaluation to demonstrate the performance of pre-coat technology?

Finally, State regulators appear to be focusing on the use of particle counters and challenge materials such as AC Road Dust, measuring counts in the 2 to 5 micron size range, as surrogates to Cryptosporidium. This avoids the use of live or fixed oocycsts and their attendant risk and expense. It also provides field testing under actual raw water conditions. If other technologies are to be required to continue field testing while membranes are allowed to substitute bench scale testing, it gives at the very least the apprearance of an uneven playing field. I strongly recommend you consider applying this modification to all other filtration technologies.

Jim Larsen
SeparmaticT Fluid Systems

Comments from Mr. Rick Pistorius, Smith & Loveless, Inc,, October 1, 2002

Dear Bruce,
Jim Bell asked that I respond to your draft for membrane bench challenge testing. I have the following comments for you to consider.

1. The term 'transmembrane' is not correct when used to describe flux.
   You should use membrane flux, water flux, or simply flux when referring to 'J'.

2. In the discussion of specific flux on pg. 7, I think it should be made clear that the appropriate diameter to be used in the calculation of membrane area should be the I.D. for the case of an inside skinned, inside to outside flow membrane.
3. Cleaning chemical concentrations should also be included in the introduction to Task B on pg. 9.
4. A bubble point test with membranes is used to determine the largest membrane pore in the membrane through a procedure of increasing air pressure to the point where liquid in the pore is displaced by air. This is not the same as the procedure you are describing on pg. 10, which should be called an 'Air Bubble Leak Test' or similar.
5. The length of the PDT described on pg. 11 is given as 15 minutes.
   This is too long a duration for some membranes. Such a long time risks drying the membrane, resulting in an inaccurately high air flow through the dry membrane. A 5 minute test is adequate to detect rapid pressure declines and indicate the presence of a defect, which is the goal of the test.
6. On pg.16 it is indicated that the manufacturer should supply a 'pore size distribution' for their membrane. This is usually meaningless (and in many cases unobtainable ) for an ultrafiltration membrane, where pores are not really pores and membrane retention is generally characterized by challenges with high molecular weight molecules. For the purposes of your report, you may want to have a manufacturer of a UF membrane give the nominal molecular weight cuttoff (NMWCO) along with a description of how that figure was determined. This could be through challenge testing with dextrans, for instance. Perhaps then you could provide an assumed conversion to an estimated pore size.

Thanks for the opportunity to comment on this draft. It is a very nice procedure that should help provide useful information about our membranes.

Best regards,

Rick Pistorius
Smith & Loveless, Inc

## Comments from Mr. Gary Logsdon, Black & Veatch, October 17, 2002

Kristie and Bruce,
Here are a few thoughts on the document. The page numbering is based on the page numbering in the file as it came up on the screen; that is, the first page is the first page of the Adobe file and not necessarily the first page of text, if that will help you sort out the page locations.

Comments are:

Editorial comment P. 6 Paragraph begins 'Since the challenge test .....' On line 3 of the paragraph change the word 'rational' to 'rationale' you are looking for a noun and not an adjective.

Editorial comment P.7 in the section labeled Bench Scale Membrane Module Requirements on line 2 the sentence reads: ' .... Materials as close to .... But 'as close to ??? Is missing'
The use of as close to implies a comparison is being made but I did not find a comparison to what in the sentence.

Editorial comment p 14. Table 2 lists only 1 protozoa but the text says 2 are listed in the table, so perhaps Giardia cysts are missing Also can E.coli be as large as 10 microns for a single cell? I don't have a reference text here at the Michigan cottage and can't look this up, but 10 microns for bacteria seemed large to me.

Read the document and it looks good to me except for the items noted above, and I think they qualify as editorial items to be changed and not major technical problems.

Gary Logsdon

## Comments from Mr. Jean-Michel Espenan, Polymem, October 18, 2002

Dear Kristie,
These are my comments on the modifications to the ETV Protocol :

First, I approved the idea for the two modifications :

Bench scale test for estimating microbial removal capability.

Suggesting in stead of requiring membrane pore size information.

My comments on the new protocol itself are :

Polymem can use one of its outside in modules both with pressure and with succion.

During Backwashing, Polymem is using air scouring. Has this to be included in the protocol ?

The lab size module to be used for the test would have to be constructed with the same fiber length, the same void ratio( number of fibers per dead volume of water to be treated) than the industrial size module to have the same hydraulics during filtration and BW. Of course, there is also a need to have the same hydraulics around (I mean for the piping around the module).

Our UF membranes (as most of the other membranes) are delivered wet, soaked in a solution of water, glycerine (anti freezing agent) and sodium bisulfite (bacteriostatic agent) They have to be rinsed with clean water (tight UF or RO water)before the test.

We do know with test performed by us and partners that the rejection of viruses is dependent not only of the operating parameters but also of the type of water used to dilute the virus (pH, salinity, organics,particles..). We think that the data got will not mean that the rejection will be the same on real site conditions but will give an order of magnitude.

For the PDT value , note (page 11) that 15 psi is too high for large pore MF membranes.

50 ppm for disinfection could be too low if the time is short. I would recommend 200 ppm if acceptable for the various materials.

From the point fo view of a membrane manufacturer it is always difficult to define the “highest operational flux” . This value is dependent of the water to treat. By that, do you mean the flux with clean water ?

In the introduction , it could be useful to precise that the rejection that is measured in the protocol is an “apparent” rejection. The “true” rejection would have to take into account that the membrane see on its surface a much higher concentration of micro-organisms or viruses than the concentration measured in the bulk solution. And so the true rejection is much higher than the apparent rejection that will be measured by the test. Note also that for a water with few viruses (usually the case for real water), if it would be possible to measure a rejection, its value would be near the true rejection value and so higher than anticipated by the test from the protocol. A simple estimation of the true rejection is to measure the rejection at various pressures and fluxes and to extrapolate a value at no flux.

Best Regards,
Jean-Michel Espenan
Polymem SA

## Comments from Mr. John Wroblewski, Pennsylvania Department of Environmental Protection, October 18, 2002

Hello from the PA DEP!

The following are the comments from the Technology Section staff on the draft Protocol for whatever nefarious purposes that may come to mind:

"....Under the "General Approach" on p. 2 it states that, "No backwashing or recirculation shall be employed during the experimental run." With no explanation provided regarding this requirement we question the reasoning and think that it would be beneficial to require backwashing or recirculation as a better reflection of actual operational conditions.

Also on p. 2 under the "Membrane Filtration Unit Experimental Set-up" section it states, "Pressurized nitrogen gas is employed to provide system pressure, since mechanical pumping can cause perturbations in pressure application." We think the manufacturer should be allowed to use whatever method they typically use to provide system pressure because all manufacturers may not use pressurized nitrogen gas.

On p. 6 under the "Bench-Scale Membrane Module Requirement" section it describes the bench-scale membrane module requirements. We question why the manufacturer wouldn't provide a full-scale module. It may be as costly for the manufacturer to develop a bench-scale module as it would be to provide a full-scale module. Why not let it up to the manufacturer?

Also on p. 6 under the "Bench-Scale Membrane Module Requirement" section it states, "a minimum of 3 bench modules shall be provided", but on the top of p. 7 it says 5 membrane modules will be evaluated. Is this a typo?

In the paragraph preceding Table 2 on p. 13 it states that 2 protozoan cysts can be used for the challenge studies; however, the table only lists one protozoa.

We also thought it might be helpful if the document provided some idea of the expected costs of these proposed modifications....."

Regards

Wrob_ski

## Comments from Mr. John Dyson, Ondeo Degremont, Inc., October 21, 2002

Membrane Protocol Comments -On the latest document, everything look OK.

## Comments from Mr. Joachim Muller, US Filter, October, 2002

*Mr. Muller agreed with the proposed approach. Comments have been transferred from handwritten comments.*

Page 4, There is no nominal pore size distribution – does not vary "nominal".
Page 4, Question about words "productivity" and "membrane area" in sentence beginning "Membranes may exhibit…."
Page 4, Question about words "the statistical distribution of " in the sentence beginning "The membrane modules used…."
Page 5, Second paragraph is hard to understand.
Page 5, second paragraph, last sentence, Question – Each module of this test?
Page 5, third paragraph, Minimum cutoff is a UF term.
Page 5, fourth paragraph, What does this mean – "…….across a range of the product line."
Page 5, fifth paragraph, question of the wording "very small ones".
Page 5, fifth paragraph, the wording "….achieve a resolution on the order of the size of a virus" is sloppy formulation.
Page 5, fifth paragraph, what is the meaning of "membrane module lot acceptance"?
Page 6, first paragraph, 0.1 $m^2$ area does not fit into ¼" fittings.
Page 6, first paragraph, 8 hours is very long!
Page 8, question on the wording of sentence beginning "Dividing by the transmembrane pressure or net driving force….."
Page 10, add "…from the feed side" to the end of the first sentence in the Air Pressure Decay Test definition.
Page 10, In the Bubble Point Test definition, the second sentence does not apply to small test modules.
Page 10, The Sonic Sensing definition does not apply to the lab.
Page 11, third paragraph, frequency does not have minutes as units.
Page 13, Pseudomonas diminuta has a new name – Brevundi mona. Size 0.2 microns?

Page 14, third paragraph, “logs” is not a unit and log has no plural “s”. e.g. “removal = 4 log “ is a very sloppy formulation.
Page 14, fourth paragraph, last sentence, why use geometric mean?
Page 16, Report Membrane Pore Size Task, Why is it still useful to compare manufacturer’s membrane pore size distribution with the measured membrane microbial removal from Task D?
Page 16. Report Membrane Pore Size Task, Good definition of ‘nominal’ pore size.
Page 16, Report Membrane Pore Size Task, Manufacturers do not always have the pore size distribution determined.
Page 16, Report Membrane Pore Size Task, Why a 90% value? As the methods are different, these data are not only useless but misleading for MF membranes.
Page 16, Report Membrane Pore Size Task, What has this work plan to do with nominal pore size?

Comments from Mr. Peter Cartwright, Cartwright Consulting, Inc., October 25, 2002

Dear Kristie,

Confirming our October 24 conversation, I have reviewed the referenced document and have a number of questions, comments, concerns and proposed changes.

It would have been nice if each line was numbered for reference purposes, but here goes.

On page 1, the last sentence of the first paragraph, I question the necessity to classify micro- and ultrafiltration membranes based on their ability to remove microorganisms. I prefer to classify these membranes based on their function and I suggest that the last sentence be eliminated.

In the second paragraph, the last two sentences are confusing to me: Why are membranes considered most vulnerable to microbial passage when they are first put on-line? The last sentence implies that a cake layer (which may tend to inhibit microbial passage?), forms "immediately after pilot plant startup". These two sentences are confusing.

Throughout the report, there is inconsistent usage of a hyphen between the words "low" and "pressure". Also the word "data" is always plural.

On page four in the first paragraph, in the sentence "Membranes may exhibit variability with respect to removal efficiency, pore size distribution (nominal and absolute)…", I would suggest removing the words "nominal and absolute". As there is significant lack of agreement in the definition of these, why include them at all?

On page six, first paragraph, the module requirements are stated as a membrane area of 0.1 m2, but it also states that "The modules shall have an effective length similar to those employed at full scale for water treatment applications". The reason for this requirement is not clear, and should be stated. Also, the seventh line down in that paragraph, the word "take" should be changed to "taken".

On page 7, under the heading "Work Plan" the second and third sentences taken together are confusing. What other operating conditions besides high flux are most likely to cause microbial penetration of the membrane? Also, the last sentence in that paragraph should be changed to "decisions on adjustments of transmembrane flux shall be made by the laboratory testing organization and consultation with the manufacturer."

Also on page 7, under the heading "Determination of Specific Flux", the terms "filtrate" and "permeate" are used interchangeably. To prevent confusion, only one or the other should be used throughout the protocol.

On page 8, in an explanation of the calculation for effective membrane surface area, only that for the "outside/in" module is listed. The formula for inside/out (lumen feed) should also be listed. Also on page 8, at the bottom, it states that an equation must be used to calculate temperature correction. What's wrong with using a chart or graph provided by the manufacturer? In my opinion, with the much higher flux

rate of microfiltration and ultrafiltration membranes, the accuracy of temperature correction is less important.

On page 11, under "Work Plan", in the last paragraph, a pressure decay test on a lumen feed module is described, but no discussion of the "outside-in" module is made.

On page 13, under "Organisms Employed for Bench-Scale Challenge Experiments", the second line should read "one protozoan cyst,…".

On page 14, under "Microbial Challenge Experiments", the fourth sentence should read, "The challenge testing shall be conducted for all organisms simultaneously, i.e., all organisms shall be seeded into the feedwater prior to conducting the testing."

In the second paragraph on page 14, the first sentence references "distilled, deionized" laboratory water. Which is it? As long as the analytical parameters are given, is it necessary to use the words "distilled" and "deionized" at all?

In the fourth paragraph on page 14, I suggest that the third sentence be changed to "At the end of this period, two discrete, consecutive samples shall be collected from the feed tank."

On page 15, I suggest that in the first sentence, the phrase "the module" be changed to "this module".

In the sentence under "Operational Data Collection", "is" should be changed to "are".

On page 16, under the paragraph labeled "Introduction", the first word of the second sentence should be changed from "this" to "these".

On page 19, in the first paragraph under "Particle Counting", what are now the second and third sentences should be combined with the word "however" preceded by a semicolon.

Also on page 19, in the first sentence under "Chlorine Preparation ion for Membrane Cleaning", the comma after "…chlorine demand free…" should be removed.

On page 22, under Appendix B, does the sentence that reads "Two-gallon pressure vessels with vacuum closure (2 gallons volume)" mean two-gallon vessels or one?

Also on page 22, what are "instant tube fittings?"

Behind the third and fourth bullets, the third dimension for the two tees is not listed. I presume it is one-quarter inch.

That's about all I have, Kristie. I hope that my comments will be useful.

Regards,

Peter S. Cartwright, PE
Cartwright Consulting Co.

6.2.2 Modification of the *ETV Test Plan for Bag and Cartridge Filtration for Particulate and Microbial Reduction* to include laboratory testing with radiolabeled microspheres.

Information gathered to date has indicated that laboratory testing with radiolabeled microspheres may be cost prohibitive. The Center is researching other options for challenge testing. Options will be discussed that the meeting.

6.2.3 Survey of 4 Ultraviolet (UV) Radiation Testing Protocols, including ETV Drinking Water Systems Center, ETV Source Water Protection Center, National Water Reuse Institute (NWRI), and the USEPA Draft Guidance.

The Center, in earlier stakeholder meetings and conference calls, had identified the concern that there are many, at least four, testing protocols for UV systems in drinking water. Consequently, the Center is developing a proposal to the New York State Energy Research and Development Authority (NYSERDA) to develop a comparison between the various outstanding UV protocols. This approach may help reduce the financial burden on the Center to harmonize UV protocols. The Center presently does not have in its budget the funds to do this alone. If stakeholders disagree that the Center should be funded for this effort, they need to indicate this or the Center will take this other approach of finding funding sources for protocol modifications and development.

### 6.3 Modification of Disinfection By-Product Precursor (DBPP) Removal Protocol Membrane Test Plan to include Natural Organic Material (NOM) humic and fulvic acid characterization.

The DWS Center received a suggestion from David Pearson, PCI Membrane Systems, at the last meeting to add Natural Organic Material (NOM) sampling as a requirement in the membrane test plan for removal of Disinfection By-Product Precursors (DBPPs). Discussion and further information on this topic to occur at the meeting.

### 6.4 Consistency on power usage measurement requirement.

The Membrane TSTP for Microbiological and Particulate Removal says: "Power usage shall be estimated by inclusion of the following details regarding equipment operation requirements: (pumping requirements, size of pumps, nameplate voltage current draw, power factor, chemical usage, etc.). In addition, measurement of power consumed shall be provided by information on current draw and power consumption." It does not give any details on how current draw and power consumption are to be measured. The Bag/Cartridge TSTP says "Electrical energy consumed by the treatment equipment shall be measured, or as an alternative, the aggregate horsepower of all motors supplied with the equipment could be used to develop as estimate of the maximum power consumption during operation." The same language is contained within the Coagulation/Filtration TSTP. The DWS Center would like to make this consistent and we would like input from stakeholders on measuring power usage vs. using ratings.

## 6.5 Percent power guidelines in test plan for UV technologies.

The Ultraviolet (UV) Radiation TSTP for Inactivation of Microbiological Contaminants does not outline the percent power that a unit needs to run at for verification testing. The DWS Center has verified three UV technologies where power has ranged from 81% to 100%. For example, the Trojan Technologies UVSwift Unit Model 4L12 ran at approximately 81% based on the manufacturer's estimate to produce a 2 log reduction of the challenge microorganism, MS2 virus. Should the TSTP outline a specific power setting instead of basing it on a log reduction so that all units are run at the same power level?

## 7. Future water security projects

### 7.1 Progress

Resulting from the terrorist and anthrax attacks of September 2001, the EPA has had several discussions with the ETV DWS Center concerning the role of the Center in assisting small communities with water security issues. One role identified by the EPA was to have the DWS Center test Point of Use (POU) devices claiming water security protection against bio-terrorism attacks. The Center for Disease Control (CDC) had found evidence of some reduction in illness from the outbreak of *Cryptosporidium* in Milwaukee in houses that had some type of POU device in comparison to those that had no POU devices. Consequently, there was interest in quantifying the extent of this additional level of protection provided by POU devices in the event of a bio-terrorist attack in a water distribution system. The ETV DWS Center has received funding for the ETV testing of POU devices designed to protect against a bio-terrorist attack.

### 7.2 For future funding consideration

The ETV DWS Center is asking for recommendations from the States and other stakeholders for the types of technologies that the Center should verify for homeland or water security protection. Some of the following technology areas have been identified, but the scope of the Center is not limited to them. Your suggestions are needed and appreciated.

- On-site disinfection technologies such as chlorine generators, chlorine dioxide generators, UV disinfection etc.;
- Temporary, complete, and portable treatment systems for emergency use; and
- System locking devices.